NASA TM - 81846

NASA Technical Memorandum 81846

NASA-TM-81846 19800020566

Conference On Automated Decision-Making And Problem Solving, The Third Day: Issues Discussed

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June 1980

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

CONFERENCE ON AUTOMATED DECISION-MAKING AND PROBLEM SOLVING
THE THIRD DAY: ISSUES DISCUSSED

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INTRODUCTION

On May 19, 20, and 21 of 1980, Langley Research Center hosted at Langley, a Conference on Automated Decision-Making and Problem Solving. The purpose of the workshop was to explore related topics in Artificial Intelligence, Operations Research, and Advanced Control Theory; and, in particular, to assess existing techniques, determine trends of development, and identify potential for application in automation technology programs within NASA. The first two days consisted of formal presentations by university representatives from each of the three disciplines in open sessions. A list of the papers presented is shown in table 1. The third day's session included the invited speakers and a small number of NASA representatives. Discussion centered on current technology in automation and how NASA can and should interface with the university community in a mutually beneficial manner to advance this technology. This paper summarizes the discussion from the third day proceedings. Proceedings of the first two days will be published separately. Editorial comment, implicit in statements made in this paper, are the authors' interpretation of what they believe to have been the viewpoint of the person making the comments or the viewpoint of the group as a whole. In the following section, the intent has been to objectively summarize the issues raised during discussions.

ROUND-TABLE DISCUSSIONS

On the third and final day of Langley's 1980 Conference on Automated Problem Solving and Decision-Making, the consultants, who had presented formal papers during open sessions of the previous two days, along with NASA representatives and a small number of invited guests, engaged in informal round-table discussions. It was expected that these discussions would summarize the important issues put before the conference and clarify points of agreement and disagreement on them. In addition, these discussions were expected to provide insight and guidance to NASA program managers and researchers in developing future NASA automation technology programs. Participants in these discussions are shown in table 2.

Jack Pennington opened the session with brief background remarks regarding NASA's interests in automation technology and, in particular, Langley's interests which led to the convening of this conference. He pointed out that Langley is presently accumulating information from universities, industry, and various government agencies to be used in determining the state-of-the-art in automated problem solving and decision-making. This task is an initial step in the present NASA Automation Technology Program, which calls for a phased build-up of an intelligent systems technology effort, beginning with the

decision process and later adding perception and ultimately effector control. Pennington proposed that perhaps the greatest benefit to current Langley interests would come from the panel formulating an effective structure or mechanism which could be used to define the state-of-the-art in automated problem solving and decision making.

Dr. William Gevarter from NASA Headquarters strongly endorsed Pennington's proposal and expounded upon it, stating that an attempt had already been made to devise a structure for doing this. It would break down the work being done in the three fields of Artificial Intelligence, Operations Research, and Modern Control Theory. Groupings might consist of examples such as "All technologies for real-time control" or "All processes that can design a plan", etc. The breakdown could include other such information as the researcher doing the work, the processing rate of the technique, and expected completion date of current research. Gevarter suggested that possibly a device like a super Venn diagram could be constructed to organize and contain this information. He expressed belief that much commonality among the methods and techniques, used by the three disciplines represented, would surface from completing the suggested groupings. He also expressed the hope that some deeper structure for the decision process might be found as well. In addition, Dr. Gevarter asked the panel to discuss the boundaries among their disciplines.

From this point on, the specific panel member expressing a particular idea or point of view will not usually be identified because this summary is preliminary and has not been reviewed by individual panel members for their concurrence.

Representatives of the Artificial Intelligence (AI) community addressed the issue of the state-of-the-art definition by stating that a structure, such as that suggested by Dr. Gevarter, could not very well be applied to Artificial Intelligence because AI is a preparadigm discipline without enough age in the subject to have a classification scheme or taxonomy of techniques. It was proposed that instead, AI might be portrayed through a series of case studies of running systems. Five to ten specific systems which are very good at specific applications and which are different enough to illustrate different approaches to problem solving might be selected. Expert systems such as Stanford's "Mycin" for diagnosing infectious diseases, or speech understanding systems such as Carnegie-Mellon's "Heresay II", are examples of these.

Although some insistence continued throughout the panel discussions that concentration on the categorizing of functions and techniques for automated problem solving continue, there was general agreement among the panel members that the process was not desirable nor likely to be fruitful. It was, consequently, not done.

One panel member observed that from the presentations of the previous two days, the interests of the presenters seemed to fall into three categories. One group was interested purely in theoretical issues. A second group was interested in numerical issues with emphasis on real-time operation and coping with the combinatorial difficulties. The third group was interested purely in symbolic computing in which functions like optimization are really not factors at all. He suggested that the latter two groups could probably benefit from

an exchange of ideas which would bring about a greater use of numbers by those interested in symbol manipulation, and vice versa.

An attempt was made by several panel members to compare and contrast the fields of AI, Control Theory, and Operations Research (OR) from the point of view of the nature of the problem area to which each is applicable and the way in which all three may interact in a complementary fashion to compose a complex problem-solving system. Within a single system the three might be thought of as forming a hierarchical structure ranging in function from strategic to tactical. Operations Research bridges the middle ground from the top-level, knowledge-based decision making of AI to the actuator control at the lowest level. It was stated that control theory operates in a space where the structure is well known, but has to deal with complicated constraints. Operations Research, on the other hand, deals with much simpler constraints, but functions in a space whose structure is more obscure. In AI there is little numerical space at all. It is, rather, an abstract space whose structure cannot be represented by geometric constraints or the like. It is constrained by knowledge, where knowledge is statements of facts. The relationships and interpretations of the three disciplines within a single system were illustrated loosely through the example of an autonomous robot with some repair task to perform. Deciding which tools to transport to the worksite is clearly the kind of qualitative reasoning which should be supplied by AI. Determining how to get to the worksite is on the boundary between OR and AI, and computing leg movements which provide stable locomotion is clearly a control function.

The Venn diagram of figure 1 was sketched by one of the consultants to illustrate the areas of common interest among OR, Controls, and Artificial Intelligence. No objections were made to the diagram or to the areas of expertise each of the disciplines could supply to each of the others. The suggestion that the broad areas on the diagram be discussed in more detail was rejected as being an exercise in exchanging textbooks.

There were some brief comments made about what the three disciplines can learn from each other. For instance, expertise from Operations Research may benefit Artificial Intelligence in managing and maintaining order in its research. Controls may be able to benefit Operations Research by giving it more knowledge and awareness of processes themselves (as opposed to purely managing them). Controls on the other hand need AI techniques to order, guide, and manage the processes being controlled.

The one issue on which the panel agreed virtually without exception was that NASA could best support interdisciplinary basic research in automation by funding some focused project. Not only did the university consultants agree on this, but they did so with much enthusiasm. The issue was raised early in the session and was the dominant theme throughout the remainder of it. Several general characteristics that the focus should have, and advantages of specific projects for advancing basic scientific knowledge were discussed and agreed upon. The project should be exciting. It should be exciting enough to capture the imagination of researchers in a number of fields and broad enough to require their talents. It should be narrow enough to fill specific NASA needs and requirements while being broad enough to fill needs that would exist even if NASA were not involved. An example of a highly focused automation project

sponsored by NASA was the project to develop an autonomous Roving vehicle to explore the Martian surface. One of the problems with the Mars Rover project, however, was that it was too specific. Only those people who wanted to go to Mars were interested in it. It was so specific that there was in it the well-defined idea that it could fail. The proposed focus should be aimed well into the future (10 to 15 years). It should have reasonable assurance of continuity and funding commensurate with its size and objectives. Finally, it should have a mechanism for pooling research expertise and results.

Focusing on a specific problem will promote organization. Once lines are defined, people tend to organize themselves along those lines. The AI people particularly seem to want something to get themselves all moving in the same direction. A suggestion was made that RFP's on focused projects could be sent out even in the absence of funding. Another argument made for a focus is that science progresses from specific applications to generalizations.

Dr. Gevarter pointed out that NASA has already chosen Automatic Sequence Generation in preparation for a planetary flyby as an initial focus in automation. At present hundreds of people require 1 to 1.5 years to complete the task manually. The work which is already in progress has found that the scheduling aspects of the problem are much more difficult than the planning. In addition, automated scheduling of ground support services for earth orbital missions is being addressed by Goddard Space Flight Center. Langley Research Center, in conjunction with the University of Illinois, is evaluating methods of error prevention and correction for automated systems.

One of the projects suggested for a NASA focus received very enthusiastic response from the panel as a whole. Essentially, a space manufacturing facility to be in operation in about 15 years was proposed. The space station would contain around 20 different kinds of teleoperators along with many other kinds of manufacturing facilities. About 20 people would man the facility and would control it from a command station of some type. The structure would be very light and flexible, thus requiring complex systems to control and stabilize it.

Comments concerning the ways in which their disciplines would like to participate in a focused NASA project were made by several panel members. Although most comments tended to relate to the candidate focus described in the previous paragraph some were more general. Operations Research expressed a particular interest in the design of the manufacturing facilities. Controls proposed to model the structure and structural dynamics of the space station in a way that will provide useful information to both the higher level reasoning and to the lower level processes which control unwanted oscillations. The information normally available to the higher level decision process is sometimes needed by the lower level controls as well. For instance, lower level controls need to be made immediately aware that a Shuttle-type vehicle is arriving so that compensatory actions can be initiated. Artificial Intelligence expressed an interest in managing the very large data based associated with the space station and performing deductive procedures on those knowledge bases. The data base could also be used to do qualitative simulations of proposed problem solutions. Constructing better and more useful data bases will require understanding how people understand how gadgets are linked together.

Several times during these discussions the possible need for a center of excellence in information sciences and automation within NASA was brought up. Apparently, some feel that focal point for these activities within NASA would afford them a more obvious, direct, and knowledgeable contact for communicating their research concerns. Likewise, they feel that the establishment of such a center would overtly demonstrate the sincerity of NASA's interest and support of this research. There did not appear to be much general interest by the group as a whole in pursuing the subject; however, the possibility was brought up that NASA might put together strawman proposals for centers of excellence and send them out to universities and others, who would critique them and respond as to how the university could interface with the new center. A viewpoint was also expressed that NASA should have a distributed center of excellence. Dr. Gevarter told the panel that the issue has been raised at the highest levels within NASA but that it has not been resolved.

Within NASA, basic research must compete with ongoing projects for funding. Because of this, it is difficult to obtain funds for new research and maintain funding continuity in current research.

There appeared to be a consensus that the Department of Defense (DOD), and the Defense Advanced Research Projects Agency (DARPA) in particular, has a much better solution to this problem than does NASA. First, DOD accepts the concept that a small, but important part of its overall funding, should be for basic research. Basic research projects, then, compete with each other for this funding, not with development projects. A second desirable characteristic of DOD funding was attributed to DARPA for the type of projects it funds. Those projects tend to be specific and focused and at the same time be of broad, general interest to the scientific community. Examples of highly successful, DARPA funded projects were cited such as: the development of the ARPANET; the project to develop a system for understanding continuous, connected speech; and the development of the universal computer language, ADA.

The Artificial Intelligence community heavily emphasized the importance of the programming language LISP in what they do and in being able to communicate with them. They cited several of its advantages. Artificial Intelligence researchers write computer programs which manipulate programs. LISP makes this easy for them. In contrast, it is almost impossible to write such programs in most other computer languages because they are organized differently and function differently from LISP. These other languages tend to be syntax intensive, which gives the code a more pleasing appearance as well as one closer to the usual way of representing the entities and functions being encoded. This characteristic, however, complicates greatly constructing programs which manipulate programs while being perhaps of trivial benefit to the programmer. LISP provides a uniform data language. That is, coded instructions are treated in just the same way as data are. The user is not disconnected from the running program and has the entire computer library available to him all the time. He can manipulate and change whatever he wants including the compiler itself. The user approaches his task from an uncommon point of view. Rather than constructing a working program, from the beginning, he constructs an experiment which he then manipulates. In addition to these advantages, the LISP environment was praised for being a community of users which enhances the productivity of its members through cooperative iteraction.

The question of establishing within NASA basic technical capabilities was raised. What mechanism could be used to effect such a transfer from the universities? How much information does NASA need and want? Is it interested in "cocktail-party" knowledge, expert knowledge, or somewhere in between? NASA representatives really did not answer these questions, except to concede that of the three disciplines only in Controls does NASA really possess considerable expertise. University representatives suggested an exchange of experts as a possible mechanism to solve the problem.

CONCLUDING REMARKS

Langley's 1980 Conference on Automated Decision-Making and Problem Solving produced a useful exchange of ideas among experts in Control Theory, Operations Research, and Artificial Intelligence. It gave NASA personnel a clearer perspective of how the academic community view's NASA's role in automation technology research.

All three disciplines agreed that as automation is applied to even larger and more complex systems and is applied in a much greater degree of completeness than ever before, that more interdisciplinary expertise will be required. They agreed that a greater awareness by each discipline of what the other two disciplines are doing is needed and that this conference was a needed step in that direction.

To determine its proper role in the future development of Automation Technology, NASA needs to know what automation technology has already been developed, what is being developed, and how NASA can acquire existing technology to use as a basis from which to move forward.

Two objectives of the conference failed to be achieved. A mechanism by which NASA could assess the state-of-the-art in automated problem solving was not defined. Likewise, no taxonomy of techniques, procedures, or methods used by the three disciplines was made.

However, as mentioned previously, NASA has a broad background in controls and is conducting and sponsoring research at or near the cutting edge of control system technology. Thus, the state-of-the-art in Control Theory by itself is fairly well known within NASA. Furthermore, one consultant volunteered to supply NASA with a review of the current capabilities in Operations Research. This review along with formal papers from the open sessions should provide a good start toward defining the state-of-the-art in Operations Research.

A state-of-the-art definition in Artificial Intelligence will probably be more difficult to put together. While being a serious problem, this difficulty is nevertheless understandable when the nature of AI as a prescience discipline is recognized.

Artificial Intelligence has not seemed to be well understood outside the confines of its own community of researchers. What it is and what its present

capabilities are have been obscure. Representatives of this community stated several important characteristics of the discipline which considerably clarified these questions. Among the more significant of these are:

1. AI is qualitative. It is a preparadigm science.
2. There is very little generality in approaches taken to problem solving; rather, approaches are problem-specific.
3. AI operates on and within a domain very different from that which defines and constrains the physical sciences. Its domain is knowledge (statements of fact) rather than mathematics and physical laws.
4. The primary tool, medium for communication, and material for constructing functioning systems is LISP and its derivative computer languages.

One concept which seemed to pervade the conference was that automation is reaching the stage in which algorithms of a strictly deterministic form will no longer suffice. A hierarchical structure must evolve in which these deterministic forms of planning, housekeeping, and control become subject to a form of supervisory decision making which is human-like (fuzzy, inexact, and nonrepeatable). This higher level decision making will come from modeling human intelligence and ultimately understanding the underlying principles through which it operates. The increasing use of heuristics (emphasized in formal presentations) is a good example of using human-like decision processes.

The academic community obviously feels strongly that NASA should define one or more specific projects through which to fund basic research. The completion of these projects and their applications should be aimed well into the future, should be assured of reasonable funding continuity, and should be broad enough to be applicable beyond NASA.

From the perspective of the conference as a whole, the following are concluded:

(1) The need for research in automation technology and the desirability of developing this expertise within NASA are recognized.

(2) Artificial Intelligence is not yet a science; it is qualitative rather than quantitative. However, it is rapidly emerging as a powerful tool to address large, complex, unstructured problems.

(3) Interdisciplinary communication and cooperations among Artificial Intelligence, Control Theory, and Operations Research have been limited, and the need to increase communication of technology between the fields was identified as the only way to solve the complex problems of large scale systems operating in space and on Earth.

(4) Combining the three disciplines into a single system results in a hierarchical structure with Artificial Intelligence the

top level management, Control Theory the bottom level worker (first-line-supervisor), and Operations Research the middle management interface.

(5) The link between automated systems and human factors was reinforced. Mechanizing decision functions now performed by man will require extensive research into understanding human intelligence and implementing new methods of human interface with these machines.

(6) The identified method for NASA to obtain expertise in automation technology is to initiate focused research resulting in the demonstration of automated problem solving capabilities, which would offer potential benefits to a broad range of complex problems.

Title	Author
NASA Crosscut Studies and Applications	Dr. William Gevarter NASA
A Framework for Automated Decision-Making and Problem Solving	Dr. Ewald Heer University of Southern California
Intelligent Controls for Advanced Automated Processes	Dr. George N. Saridis Purdue University
Implications of Behavioral Decision Theory for Automatic Decision-Making and Problem Solving	Dr. William R. Ferrell University of Arizona
Problem Solving with Uncertain Knowledge	Dr. Bruce Buchanan Stanford University
Sequential Decision-Making and Stochastic Networks	Dr. Salah Elmaghraby North Carolina State University
Distributed Problem Solving and Natural Language Understanding Models	Dr. Charles Rieger University of Maryland
Application of AI Problem Solving Techniques to Computer-Aided Design	Dr. Gerald Sussman Massachusetts Institute of Technology
Systems Modeling Past, Present and Future as Viewed from a Network Modeling Perspective	Dr. Gary Whitehouse University of Central Florida
Recent Research in Network Problems with Applications	Dr. Gerald L. Thompson Carnegie-Mellon University
Problem Solving in Distributed Systems	Dr. Richard F. Rashid Carnegie-Mellon University
Large Scale System Theory Decentralized Control	Dr. Robert Tenney Massachusetts Institute of Technology
Decentralized Control	Dr. Jason L. Speyer University of Texas

Table 1. Papers Presented During Open Sessions

TABLE 2. ATTENDEES OF FINAL SESSION

Name	Organization
Dr. Willard Anderson	NASA, LaRC
Dr. L. Keith Barker	NASA, LaRC
Dr. Bruce Buchanan	Stanford University
Dr. Robert Chien	University of Illinois
Mr. Richard DesJardins	NASA, GSFC
Dr. Salah Elmaghraby	North Carolina State University
Dr. William Ferrell	University of Arizona
Mr. Leonard Friedman	Jet Propulsion Laboratory
Dr. William Gevarter	NASA Headquarters
Mr. Walter Hankins	NASA, LaRC
Dr. Ewald Heer	University of Southern California
Mr. Ronald Larsen	NASA, GSFC
Mr. Jim Long	Jet Propulsion Laboratory
Mr. Jesse Maury	NASA, GSFC
Mr. Alfred Meintel	NASA, LaRC
Mr. Jack Pennington	NASA, LaRC
Mr. Lloyd Purves	NASA, GSFC
Dr. Richard Rashid	Carnegie-Mellon University
Dr. Charles Rieger	University of Maryland
Dr. George Saridis	Purdue University
Mr. Al Schy	NASA, LaRC
Dr. Jason Speyer	University of Texas
Dr. Gerald Sussman	Massachusetts Institute of Technology
Dr. Robert Tenney	Massachusetts Institute of Technology
Dr. Gerald Thompson	Carnegie-Mellon University
Dr. Gary Whitehouse	University of Central Florida
Dr. Leonard Yarbrough	NASA, MSFC

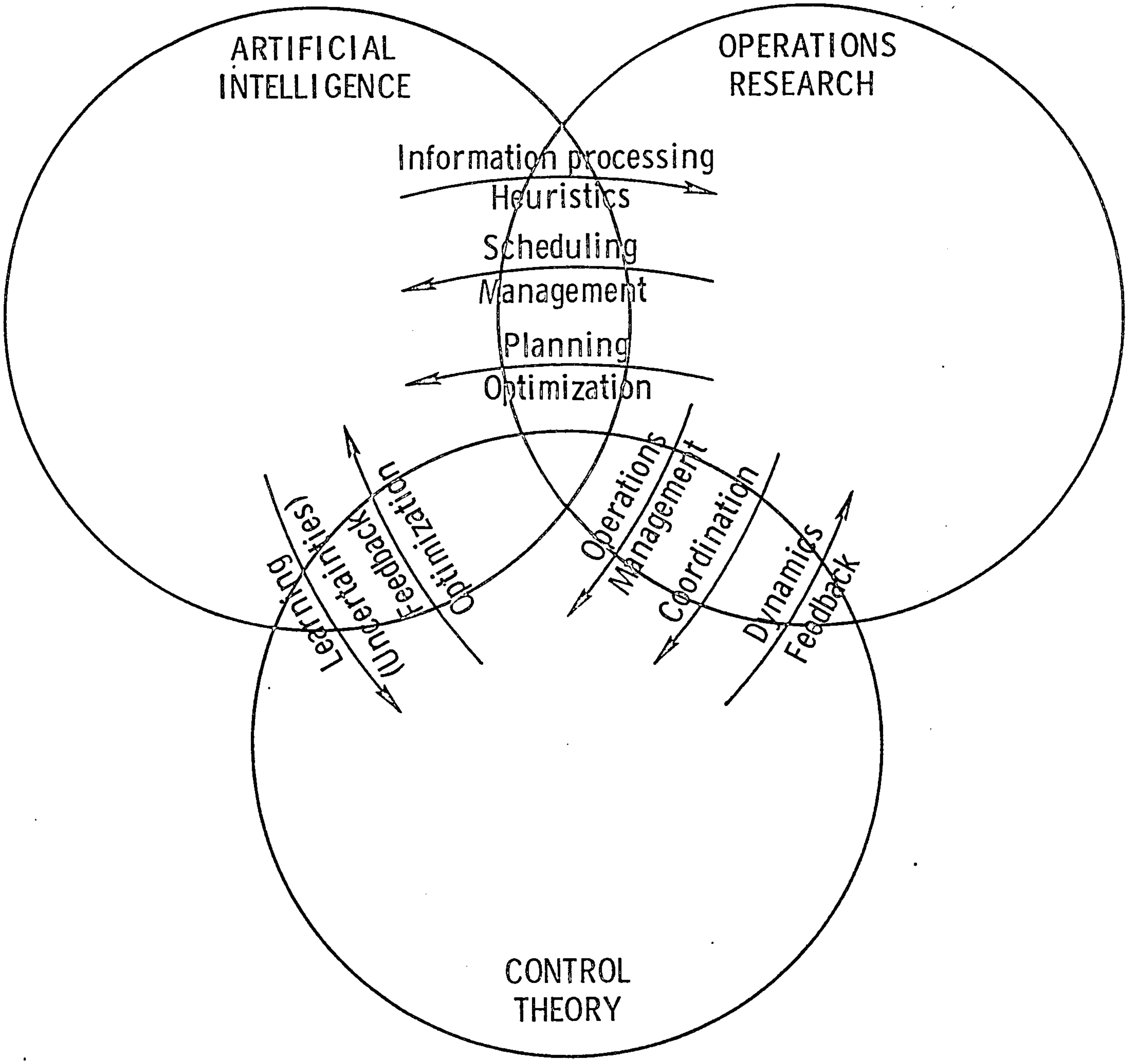

Figure 1. - Venn diagram of interdisciplinary issues and expertise.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-81846		

4. Title and Subtitle	5. Report Date
Conference on Automated Decision-Making and Problem Solving, The Third Day: Issues Discussed	June 1980
	6. Performing Organization Code
7. Author(s) Walter W. Hankins, Jack E. Pennington, and L. Keith Barker	8. Performing Organization Report No.
	10. Work Unit No. 506-54-13-02
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665	11. Contract or Grant No.
	13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	14. Army Project No.

15. Supplementary Notes

16. Abstract

This paper summarizes informal discussions from the final day of a three day conference on Automated Decision-Making and Problem Solving. The conference which was held at Langley Research Center in May of 1980 brought together university experts from the fields of Control Theory, Operations Research, and Artificial Intelligence to explore current research in automation from both the perspective of their own particular disciplines and from that of interdisciplinary considerations.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Artificial Intelligence Decision making Machine intelligence Problem solving Automation Control Theory Operations Research	Unclassified - Unlimited Subject Category 63

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	11	A02

*For sale by the National Technical Information Service, Springfield, Virginia 22161